Concept Development and Experimentation Policy and Process: How Analysis Provides Rigour

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ABSTRACT

NATO's Military Committee has recently approved the MC-0583 Policy for NATO Concept Development and Experimentation (CD&E). The policy aims to set out the role of CD&E in support of the Alliance's transformational goals, to clarify responsibilities of the various actors, and to provide a robust basis for defining a detailed CD&E process within NATO. It describes the nature of NATO's CD&E as a tool for adapting the Alliance to future challenges, its position within NATO capability development and the relationships with other related processes. CD&E is one of the tools that drive NATO's transformation by enabling the structured development of creative and innovative ideas into viable solutions for capability development. Capability development covers strategic analysis, identification of capability requirements, solution identification and solution implementation. Capability requirements may result from the assessments of potential future requirements, medium term defence planning requirements, lessons learned or urgent operational requirements. In finding conceptual solutions to capability shortfalls and gaps that were identified in other processes, CD&E plays an important role, but also CD&E contributes to capability development through the introduction of previously unknown capabilities that result from new ideas, "out of the box" thinking or simply Research and Technology endeavours.

The role of Analysis in the CD&E process is obvious. Analysis can determine in an early stage the stakeholders' interests in the concept and their expectations, the operational value and the feasibility of the concept, and determine possible venues for development by addressing operational validity and effectiveness through modelling. Analysis supports the conduct of experiments through a proper formulation of hypotheses and expectations to ensure that the outcomes of experiments inform the concept development. As the development of a concept progresses the analysis activities look to accumulate evidence to determine and demonstrate the validity and increased effectiveness of the proposed solutions. As such the rigour of the analysis is important to increase confidence in a conceptual solution and reduce the risk involved with its implementation.

Keywords: *CD&E, Concept Development, Experimentation, Operational Analysis.*

1. INTRODUCTION

In 2004 the revision of the NATO Military Command Structure[1] and the Terms of Reference[2] of Supreme Allied Commander Transformation (SACT) were approved by the Military Committee (MC) specifying the

[1] MC 324 – NATO Military Command Structure – 7 May 2004 / Nov 2009

[2] MC 58/2 – Terms of Reference for the Supreme Allied Commander Transformation – Nov 2004 / Nov 2009

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NATOs Military Committee has recently approved the MC-0583 Policy for NATO Concept Development and Experimentation (CD&E). The policy aims to set out the role of CD&E in support of the Alliance's transformational goals, to clarify responsibilities of the various actors, and to provide a robust basis for defining a detailed CD&E process within NATO. It describes the nature of NATO's CD&E as a tool for adapting the Alliance to future challenges, its position within NATO capability development and the relationships with other related processes. CD&E is one of the tools that drive NATO's transformation by enabling the structured development of creative and innovative ideas into viable solutions for capability development. Capability development covers strategic analysis, identification of capability requirements, solution identification and solution implementation. Capability requirements may result from the assessments of potential future requirements, medium term defence planning requirements, lessons learned or urgent operational requirements. In finding conceptual solutions to capability shortfalls and gaps that were identified in other processes, CD&E plays an important role, but also CD&E contributes to capability development through the introduction of previously unknown capabilities that result from new ideas, out of the box thinking or simply Research and Technology endeavours. The role of Analysis in the CD&E process is obvious. Analysis can determine in an early stage the stakeholders interests in the concept and their expectations, the operational value and the feasibility of the concept, and determine possible venues for development by addressing operational validity and effectiveness through modelling. Analysis supports the conduct of experiments through a proper formulation of hypotheses and expectations to ensure that the outcomes of experiments inform the concept development. As the development of a concept progresses the analysis activities look to accumulate evidence to determine and demonstrate the validity and increased effectiveness of the proposed solutions. As such the rigour of the analysis is important to increase confidence in a conceptual solution and reduce the risk involved with its implementation.

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responsibilities of Allied Command Transformation (ACT) to lead in Transformation. NATO Transformation seeks to increase the levels of interoperability and standardization and enhance cooperation and collaboration between NATO nations. This step affirmed the MC decision[3] to adopt CD&E as the Alliance tool to explore, demonstrate and evaluate future operational concepts that drives changes in NATO's capability development. CD&E has evolved over the years to be the primary tool in finding solutions to conceptual gaps identified within NATO's capability shortfalls.

In 2009 the MC approved the Policy for NATO CD&E[4] setting out the principles of CD&E and how it supports the NATO's Transformational Programme. A subsequent document, the CD&E Process, is in draft, and aims to build upon the CD&E Policy to provide guidance on the implementation of CD&E activities within NATO, or more specifically, to elaborate on how CD&E should be understood, directed and coordinated with the emerging NATO Defence Planning Process, the established Lessons Learned Process and the operational requirements from current NATO operations. It specifies how CD&E activities are organized in NATO around CD&E projects, and how these projects are managed, funded and tracked, how quality assurance is applied and how NATO engages the nations in sharing methods and results.

The embedding of the CD&E process within the current and emerging NATO processes has become of utmost importance in an era within which nations are requesting NATO to formulate common goals in terms of capabilities, rather than force contributions to NATO. The fuzziness of setting targets for nations and NATO in capability terms creates an uncertainty of what other NATO processes are producing. An increasing need to understand all processes in NATO is the wish from the nations to relate all of them for a coherent view of what nations are providing, need to provide in future, and are willing to provide as defence contributions to the Alliance. As such the CD&E process relates to Defence Planning in the search for solutions for capabilities that are identified as shortfalls but for which no current or obvious solution exists. On the other hand products from the CD&E process may alter the view on how NATO operations must be conducted, how the military forces must be trained, what new technologies will be available in future to be incorporated in new equipment and facilities, etc changing the way in which Defence Planning may derive requirements in the future.

This development requires the ability to conceptualize new ideas and bring those to fruition. Within concept development, new ideas are developed, discussed, scrutinized, criticised, and gamed in order to understand all aspects of the shortfall and the proposed solutions for that shortfall. Subsequent experimentation brings this further into an operational environment in order to discover, hypothesize or validate the new ideas that have been formulated in the concept. Since the start of CD&E activities, ACT has relied heavily on the Guide for Using and Implementing Defence Experimentation (GUIDEx)[5] for the design of CD&E campaigns. ACT has been reasonably successful in the implementation of rigour through analysis in Experimentation efforts but only recently has begun to support Concept Development with analytical methods and tools.

This paper details on the specifics of NATO CD&E analytical efforts and how Operational Analysis has become an integral part of NATO CD&E. It will also explain how NATO CD&E attempts to collaborate and cooperate with NATO's Research and Technology initiatives.

2. CD&E POLICY AND PROCESS

The MC 583 Policy describes the nature of NATO's CD&E as a tool for adapting the Alliance to future challenges, its position within NATO capability development and the relationships with other related

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[3] MCM-0133-2000, NATO Concept Development and Experimentation (CDE), 7 Sep 2000

[4] MC 583 – Policy for NATO CD&E, 30 Sept 2009

[5] GUIDEx – The Technical Cooperation Program (TTCP), March 2006

processes. CD&E is one of the tools that drive NATO's transformation by enabling the structured development of creative and innovative ideas into viable solutions for capability development. Normally development of concepts is conducted in an iterative manner and spiral improvement is obtained through successive experimentation. CD&E contributes to the continuous transformation to keep NATO relevant in the security environment and to enable NATO to carry out its roles effectively. The primary purpose of CD&E is to provide credible solutions to capability shortfalls. The CD&E aims at capturing the best ideas and enabling potential solutions to be explored through Concept Development, tested and validated through Experimentation, either within NATO or collaboratively with nations.

Capability development covers strategic analysis, identification of capability requirements, solution identification and solution implementation. Capability requirements may result from the assessments of potential future requirements or the identification of the Minimum Capability Requirements (MCR) which are steps within the Capability Requirements Review and part of the NATO Defence Planning Process. That process is further enhanced and informed by urgent operational requirements and Lessons Learned process. Evidence from ongoing operations or exercises, complemented by strategic and operational analysis, often identifies important information to support the assessment of capability shortfalls in the NDPP. Eventually, all that information leads the NDPP to determine the identification and prioritization of capability shortfalls. In the solution finding phase, CD&E plays an important role when innovative answers are needed particularly when potential solutions involve developing new approaches to operations, new procedures, new organizational structures and the application of new technologies, or when lessons identified request CD&E support in developing and refining proposed solutions. These are considered to be the primary sphere for CD&E.

While CD&E primarily develops conceptual solutions for capability shortfalls already identified by other processes, it can also contribute to capability development through the introduction of previously unknown capabilities. New ideas may result from "out of the box" thinking or may be gained from Research and Technology (R&T) endeavours. A new or emerging technology or technique may be identified as having a potential for a military application within NATO. This could be turned into a potential new capability and developed through CD&E if an operational benefit could be expected. The new ideas may influence the NDPP process in its next cycle to develop new capability requirements. This is considered the secondary sphere for CD&E.

2.1 Concept Development

The role of Concept Development is to identify recommended solutions to capability shortfalls or gaps. New problems may be brought about by some combination of political, social, economic, technological, doctrinal factors, or by the introduction of new objectives to a pre-existing situation. A new concept may also be developed to propose a better solution than currently exists. This solution may be delivered through technological, organizational, tactical, societal or other developments that did not exist before, or it may be required due to the failure of an existing but sometimes obsolete concepts. A basic distinction can be made between strategic and operational concepts. The first type contains political or high level politico-military assessments, objectives and guidance. These concepts also generally encompass a broad strategy on which military operations are to be based or provide a vision for the Alliance for the mid to long-term future. They may address key elements of NATO's defence posture, such as command or force structure or contain a broad military strategic framework. Their development might lead to the identification of CD&E projects. The second type addresses the levels at which campaigns and joint operations are planned and conducted in order to accomplish strategic objectives within a theatre of operations. These concepts are normally the overarching element of a CD&E project. Concept development provides the framework within which a solution may be developed. Solutions may or may not be refined through experimentation, but require validation in every case.

2.2 Experimentation

The role of experimentation is primarily to determine whether a concept under development will achieve its desired aim. Results from experimentation inform the concept developer whether a whole concept (or elements therein) are sound or flawed. Experimentation reduces uncertainty as to whether a concept or parts thereof have reached the required level of maturity, helps to identify and solve problems that cannot be solved through studies and analysis alone and avoids those developments which do not offer added value. Moreover, experimentation, as a 'trial and error' methodology, can also exploit a negative outcome as a way to refine concepts.

Experimentation can occur at each stage of Concept Development so that a single conceptual idea could give rise to one or more discovery, hypothesis testing and validation experiments. Therefore, the conceptual rationale for Experimentation could range from an initial conceptual idea to an approved concept. The important aspect is that the process be cyclical: Concept Development provides the rationale for Experimentation and Experimentation provides information to refine the concept. Assessment and refinement should involve subject matter experts and concept's customers to the maximum possible extent. Additionally, Experimentation can also be conducted throughout the implementation phase of a concept.

2.3 CD&E Projects

CD&E is a scientifically supported methodology applied to the development of a capability when a conceptual gap has been identified. The application of the CD&E methodology requires an inherent evaluation and controlling process in order to ensure conceptual coherence, experimental control in execution, and rigorous and unbiased analysis of expectations and results. The decision to initiate a concept should be made after a thorough analysis of the capability shortfall that encompasses a stakeholder analysis, problem identification and structuring and a brainstorming of ideas. Subsequently, a CD&E project is started to develop and validate the concept and it includes:

a deeper analysis of the problem and identification of possible conceptual solutions;
the drafting of a concept;
the development of solutions;
the analysis of the adequacy of the solutions; and
experimentation to hypothesize, refine or validate the proposed solutions.

In general, a CD&E project employs an iterative and spiral development approach. “Concept development”, “experimentation” and “analysis” are the main ingredients of a CD&E project. While concepts could be developed in many different ways, the utilization experimentation and analysis guaranties the ‘testing’ of the concept within an operational environment combined with robust and rigorous analysis in quantitative or qualitative form of conceptual outputs. The characteristic and the intensity of these individual elements can be different, dependent on the topic. However none should be excluded from the beginning and, during the development cycles (spirals of development) their use must be considered at each time. The CD&E project covers the development of the concept until the implementation phase, where decisions are made with respect to acquisition and application of the proposed conceptual solutions.

The CD&E process encompasses the use of the CD&E methodology in the development of all needed projects, the management of related activities and the engagement with nations and within NATO. The main activity of CD&E occurs within the CD&E projects in initiation, developing and validating the concept and readying it for approval. CD&E projects can be initiated by direct guidance from the MC, through an

operational request from theatre, or by internal direction in reaction to an identified shortfall derived from the NDPP or a Lesson Learned, recommendations from R&D, R&T or nations. The management includes the assembly of CD&E project proposals, justification and validation of CD&E activities, resource allocation and funding, and integration of activities in ACT's plans. Management also enforces Quality Assurance that includes custodianship of the CD&E process itself, overall concept coherence, sound and robust analysis, adherence to scientific rigour, experiment control, coordination and compliance. CD&E Engagement includes the dissemination and socialization of results, spreading and sharing knowledge on CD&E methods, processes and projects in order to promote best practices amongst NATO nations and partners.

3. ANALYSIS IN CD&E

While discussion on what constitutes a good concept, what are best practices for concept development, how to conduct experimentation etc are topics that deserve utmost attention, the aim of this paper is to concentrate on the contribution that analysis brings to the CD&E process. In doing so, however, it is evident and unavoidable that some best practices in concept development and in experimentation will be discussed, and that is believed to be appropriate and in the best interest of all.

3.1 Operational Analysis

According to NATO definitions[6] analysis is defined as "the study of a whole by examining its parts and their interactions", while the US Training and Doctrine Centre defines analysis as "the examination of a complex whole, its elements and their relationships to inform senior leader decisions or to gain understanding of complex problems[7]. In that context we can define what Operational Analysis (OA) by quoting from the SAS 044 Report[8] which defines OA as "the application of scientific and quantitative methods to assist decision makers". In general, Operational Analysis is more scientifically based and - in contrast to engineering sciences – looks at the entire system, taking into account all constraints, to scope a problem to determine its operational usefulness. In doing that, the OA analyst is occupied in the scoping and structuring of problems, in solution definition and comparison, in optimization and risk and cost-benefit analysis, in data collection and interpretation, amongst others. OA uses techniques that are derived from mathematics and statistics, social and physical sciences, and is a heavy user of modelling and simulation techniques, but in reality the main tool in use is common sense and logic. The main goal of OA analyst is to bring forward those aspects of a problem that determines it sufficiently to support decisions by management, and the result of analysis is improved understanding of the topic under study.

The need for analysis is justified by the fact that the world is too complex to permit immediate understanding of any new idea, concept, situation or topic, and particular in defence related matters the complexity of the operational environment calls for the use of well-founded principles from science and experience to be applied in a rational and logical manner. However, the challenge that the analyst faces is that, as David Galula said, "war is not a chess game, but a vast social phenomenon with an infinitely greater and ever expanding number of variables, many of which elude analysis"[9], which may set its limits on how analysis alone can shed light on defence issues, and therefore the urge is to set analysis next to other ways and means to examine the problem set with which we in the defence world are confronted with. The analytical process follows a more or less

[6] AAP-6 – NATO Glossary of Terms and Definitions, NATO Standardization Agency, 2009

[7] US TRADOC Regulation 10-5-7, U.S. Army Training & Doctrine Analysis Center

[8] RTO SAS-044 Report – "Code of Best Practices for Decision Support to Combined Joint Task Force and Component Commanders", AC/323(SAS-044)TP/46, December 2004

[9] David Galula – Counterinsurgency Warfare Theory and Practice, 1964, p. ix

standard way of formulating and stating a problem, build a function model, observe how the problem manifests itself in the real world, and then resolve anticipation and realization of the problem's behaviour and draw conclusions. In formulating the problem, the analyst frames, defines and scopes the problem by providing background, precision and clarity, customer and stakeholder's interests, and limitations, constraints and restraints, after which he determines the aims and objectives of what the problem seeks to solve. While the analyst builds a functional model, she conducts research to investigate the underlying logic and mechanisms that could govern the problem and postulate what the expectations could be from a theoretical model. In doing so she should distinguish between the ideal and the intended or desired models to approach the reality as much as possible. Subsequently, the analyst conducts a decomposition of the problem into its parts and components and determines the relationships between them. In preparation of the observation of how the problem manifests itself in the real world, a plan is designed to observe and measure, which will enable the actual observation and collection of measurements to be conducted. In doing so the analyst must ensure to distinguish between the actual and the perceived reality. From the observations he will conduct the sampling and surveying and retrieve necessary measurements. Finally, the analyst will resolve anticipation and realization of the problem's behaviour and draw conclusions through contrasting and comparing expectations against measurements, theoretical model against reality, after which results are analyzed and the findings validated. This enables him to prove or disprove expectations, allowing him to report his conclusions and make recommendations. In summary, analysis brings structure and rigour in the definition of problems, in methods and in results. Analysis may be quantitative, or qualitative, but most importantly, analysis brings meaning by making better sense of the world.

3.2 Wicked Problems

Analysis in CD&E encounters the challenge that the problems the shortfalls in capabilities pose prove mostly to be difficult and non-intuitive. They generally fall into the class of so-called "wicked" problems[10]. Wicked problems are problems that are un-bounded and ill-defined, are novel but difficult to conceive, and have multiple and conflicting goals and customers. A wicked problem is one for which each attempt to create a solution changes the understanding of the problem. Wicked problems cannot be solved in a traditional linear engineering fashion, because the problem definition evolves as new possible solutions are considered and/or implemented. Most projects in organizations -- and virtually all technology-related projects these days -- are about wicked problems. Indeed, it is the *social complexity* of these problems, not their technical complexity, that overwhelms most current problem solving and project management approaches. It is therefore that the Concept Developer cannot approach the problem of developing a concept as "normal" staff work, and need to have a method to tame the wickedness of the problem. As analysts have been trained to study complex and messy

ASPECTS OF PROBLEM WICKEDNESS

- ***You don't understand the problem until you have developed a solution.*** Indeed, there is no definitive statement of "The Problem." The problem is ill-structured, an evolving set of interlocking issues and constraints.
- ***Wicked problems have no stopping rule.*** Since there is no definitive "The Problem", there is also no definitive "The Solution." The problem solving process ends when you run out of resources.
- ***Solutions to wicked problems are not right or wrong,*** simply "better," "worse," "good enough," or "not good enough."
- ***Every wicked problem is essentially unique and novel.*** There are so many factors and conditions, all embedded in a dynamic social context, that no two wicked problems are alike, and the solutions to them will always be custom designed and fitted.
- ***Every solution to a wicked problem is a "one-shot operation,"*** every attempt has consequences. As Rittel says, "One cannot build a freeway to see how it works." This is the "Catch 22" about wicked problems: you can't learn about the problem without trying solutions, but every solution you try is expensive and has lasting unintended

10 Horst Rittel and Melvin Webber - Dilemmas in a General Theory of Planning, 1973

decision making problems in organizations and systems that undergo change, analysis support and assistance is frequently sought by Concept Developers to provide advice. Frequently, analysts organize and facilitate brainstorming, and gather ideas and thinking of a group of experts. As the group's understanding of the problem evolves, solutions emerge through the shared commitment of needing to create a durable solution. Understanding a wicked problem is about collectively making sense of the situation and coming to shared understanding about *who* wants *what.* In Experimentation the wickedness of the problem is manifested in the inability to attribute changes to the phenomenon under observation to the introduced new conceptual ideas, prototypes or treatments. The analyst's ability to observe, sample and separate coincidence from cause, is another way to tame the wickedness of the problem. Table 1 gives some examples of tame and wicked problems.

Table 1 - Tame vs Wicked Problems

Tame	Wicked
Expelling Iraqi Forces from Kuwait in 1991	Deciding whether or not to attack Iraq again in 2003
Quelling a riot at a World Cup football game	Quelling the current civil and religious strife in Iraq
Modifying all a nation's military aircraft to receive Link-16	Deciding why
Writing an EBAO Guide to Operational Planning	Deciding how to incorporate this into existing NATO doctrine
Building a network of renewable energy sources in a country	Deciding what to do when oil runs out
Putting a man on Mars and returning him safely to earth	Writing an international law on militarization of space

3.3 Phases of CD&E Project

Although the CD&E Policy and Process documents define a CD&E project as a concurrent, iterative and spiral process in which conceptual work, experimental efforts, analytical insights are intermingled to form a process that employs all trades from drafting of documents, brainstorming, war-gaming, research and analysis, M&S, live experiments, and prototyping to demonstrations, there is still a tendency to separate the Concept Development from the Experimentation part of the project. There is some merit in this approach, although from an Analysis point of view, it would be better to think in an integrated manner, mainly to ensure that Analysis gets its proper place within the CD&E project. The CD&E project can be subdivided into four phases:

a. Concept Initiation: the decision to start a CD&E project, after problem and customer requirement have been identified. Initial research and formulation of the problem is started;

b. Project Planning: develop a Concept Development Plan (CD Plan) for the co-ordination and management of the project. It is used to assign tasks and responsibilities, monitor the progress of these tasks, integrate and synchronize efforts of multiple teams or people with different competencies, co-ordinate and integrate activities;

c. Concept Development: the spiral process of development and refinement of proposed solutions according to the CD Plan;

d. Concept Assessment and Validation: the integration of experimentation, providing opportunities to discover, speculate, hypothesize and validate conceptual ideas within the context and the progress of the concept.

Analysis supports each of these phases in its own special way. As stated before, defence problems nowadays appear to be not suited for normal solution methods and the problems are generally 'wicked'. Most of the

time, the requirements are difficult to define or the goals are difficult to formulate. Customers are not sure or do not know what they want exactly, and if a solution is found, it is difficult to verify or to test if that is the right solution. In more general terms, it is hard to say whether the final concept with its solutions is "correct".

3.3.1 Preparation, Initiation and Structuring

The analysis supports the initiation of the project by identifying and scoping the problem and the customers' requirement by asking questions such as what the real problem is or what the problem really is, who the customer is, and why a concept is needed. The analyst can do this, as he/she has undertaken in preparation of the project a literature search to understand the context of the problem. This literature search, also known as Baseline Collective Assessment is a historical evaluation of causes of the problem, and a history of development to data to include operational factors, a detailed review of documents related to subject area, relevant technology and experimentation. This review is necessary to gain understanding and expertise and to avoid duplication. An analyst is normally academically trained to undertake this task.

In problem formulation, the problem must be scoped and structured and analysis is required in both of these steps. It is the most difficult phase of a CD&E project and the analyst will have expertise in specific techniques normally not possessed by military staff officers. In scoping, it is mandatory to undertake a stakeholder analysis to identify the customers, players and those who are affected by the concept, the interpretation of the baseline concept assessment must be taken into account, and a common understanding of what the problem is by all stakeholders must be established. In problem structuring the aim is to develop an understanding of the core issues to be addressed by the concept. That includes:

Conduct an initial assessment of its value and relevance;
Conduct analysis of operational benefits to support the need statement;
Justify the operational benefits and determine the feasibility with case studies, research and technology;
Determine linkages and interdependencies with other concepts and capabilities;
Determine how concept might affect other policy, doctrine or other concepts in development;
Determine necessary tasks and required skills/knowledge needed to move forward;
Risk Analysis.

In this phase, the techniques used by the analyst include soft-systems methodology, rich picture analysis, strategic choice approach, SWOT analysis, morphological analysis, System Dynamics modelling, causal and cognitive mapping, workshop facilitation and gaming.

3.3.2 Concept Development Plan

The CD Plan is formulated to manage the CD&E Project. It provides the roadmap, the project structure, the organization and timelines for the Concept Development and Experimentation. It manages the expectations of the stakeholders and deals with the necessary resource implications of funds and manpower. It may be the most overlooked phase in the theory of CD&E. The analyst must ensure that during the construction of the CD Plan adequate resources are devoted to the analytical activities so that the ultimate goal of analysis of providing quality assurance can be obtained.

3.3.3 Development and Refinement

In the phase of concept development itself, the CD&E project is seeking to execute its CD plan through the actual drafting of a concept document *and* development of solutions maturing the ideas that have been

hypothesized in the concept document, which in principle should state what the problem is and why it is needed, imagine how it may be done, and infer to the capabilities and conditions it needs to be able to succeed. According to the CD&E Policy a concept is "a solution-oriented transformational idea that addresses a capability gap" by addressing solutions over the DOTMLPFI[11] spectrum.

Understanding that in developing a concept, the problem that the concept seeks to address is difficult to imagine and does not lend itself to a stepwise description of directions to take or procedures to follow – due to the fact that the conceptual problem is mostly a wicked problem – there is a need for an iterative, spiral-like campaign, that will constantly review and reshape the concept through reassessment of the problem, the hypotheses, the solutions, the risks and the stakeholders' needs. The GUIDEx uses the term of "on-going campaign analysis" to describe this framework. This will ultimately lead the concept developer to request different and more mature analytical methods, to include modeling and simulation, analytical studies and ultimately operational experimentation. The latter is used to reduce the uncertainty in impact of the concept and to accumulate evidence that in an operational setting the proposed solutions are measuring up to the expectations of the stakeholders.

Initially, analytical methods employed are simple as in the problem formulation stage, but when some of the ideas mature the application of more sophisticated methods are necessary. Optimisation, risk and cost-benefit analysis could be applied during this phase. Process and organization issues are mostly complex and have to be dealt with by process (flow) modelling, organizational analytics, however, in general, modelling starting from Systems Dynamics to the advanced Combat Simulations may need to be applied. Remember that not all problems fit the mould of the problem that a particular established campaign or combat simulation is built for to solve: doctrinal and organizational issues may be hard-coded features of these models and flexibility to change them may not be present. Modelling and Simulation (M&S) may help to answer the problem and could reduce the need for the more expensive operational experimentation. Alternative methods such as table-top gaming, structured brainstorming, historical analysis or subject matter expert seminars or workshop may be required as part of the campaign of analysis. In order to conduct M&S, it is imperative to collect data to feed models and simulations. Additionally, metrics and measurements have to be prepared and developed to ensure that the final phase of assessment and validation of the concept can take place. Simple metrics that cannot be collected other than in an operational setting – normally performance parameters of weapon and C4I systems and logistics can be obtained from other sources – are information flow rates, time delays, common intent etc. M&S supports the conduct of an analytical study.

3.3.4 Assessment and Validation

For complex and large capability development problems, a means of measuring the concept's benefits and risks are to expose it into the operational environment. While analytical methods, essentially rational and deductive, provide immediate benefits in the early stages of concept development, experimentation allows for the empirical deductive or inductive methods to benefit the concept. Care should be taken that experimentation and analysis are integrated into one campaign. A campaign that uses a mix of experimentation and analytical studies and methods will inherently increase the understanding and solution of the conceptual void.

The CD&E Policy describes three types of experimentation: (1) discovery experiment to find out something that wasn't known before; (2) hypothesis testing experiment to test something to see if it works and then refine; and (3) demonstration experiment to demonstrate that something works. In practice these definitions have led military staff to believe that for a discovery experiment a mere curious attitude would be enough to

[11] DOTMLPFI = Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities and Interoperability.

conduct an experiment. The GUIDEx, however, states that for any experiment the "if I do this, what will happen" question[12] is the underlying paradigm that guides any experiment: manipulate something to see what happens. Therefore expectations on causes and effects must be made before the conduct of any experiment, and thus in principle, all experimentation is hypothesis based.

The hypothesis – in short the phrase "If 'Cause' Then 'Effect'" – underlies the design of any experiment. A *good* or *valid* experiment provides information to ascertain whether the 'Cause' caused the 'Effect', or whether A caused B. First of all, we have to ensure that capability A can be used in the experiment, secondly, we have be able to detect a change in B, then we have to be able to determine if the change in B is really caused by the change in A, and finally, we have to be able to explain why the results of the experiment can be generalized to the operational environment. Several experimental designs are available that strengthen one validity requirement while diminishing the value of the other. Control of the variables is more likely in simulations, while in analytic wargames human variability is introduced which is becoming less manageable in human-in-loop simulations and may be difficult to control in live exercises. Successful experimentation seeks to diminish the risks that are posed in conduct of the experiment by a rigorous design that acknowledges the constraints and benefits from the knowledge gained from earlier analysis and concept development, by meticulous planning that minimizes the risks, by strict conduct using a control regime and a comprehensive data collection and analysis plan. As such analysis has a significant role to play to ensure that the criteria for good experimentation are followed with the aim of establishing:

Validity: It will do what we expect it to do
Feasibility: We can do what we want given the constraints
Applicability: It make sense given the situation
Robustness: It can withstand criticism
Credibility: Information gained contributes to the sum of our knowledge

Frequently, experimenters are conducting their experiments with the notion that analysis only needs to occur after the results are obtained, and only admit – prior to the conduct of the experiment – a role for the analyst as the drafter of the data collection and analysis plan. The relegation of analysis to conduct the collection of observations, to administer surveys and questionnaires, to perform statistical analysis on the results, and to draft an analysis report annexed to the experimentation report, has the built-in risk that the experiment may not observe and measure the desired impact of the changes in A that effect B. There is a rightful place for the analyst in the design of the experiment to ensure the desired outcome of the experiment can be obtained. Moreover, the analyst may be the right hand of the concept developer to problem formulation, structuring and solution finding, and could be the prime staffer in the conduct of structured brainstorming, analytical wargames, and the application of M&S.

[12] R.P. Feynman – The Meaning of it All: Thoughts of a Citizen Scientist, USA, 1999

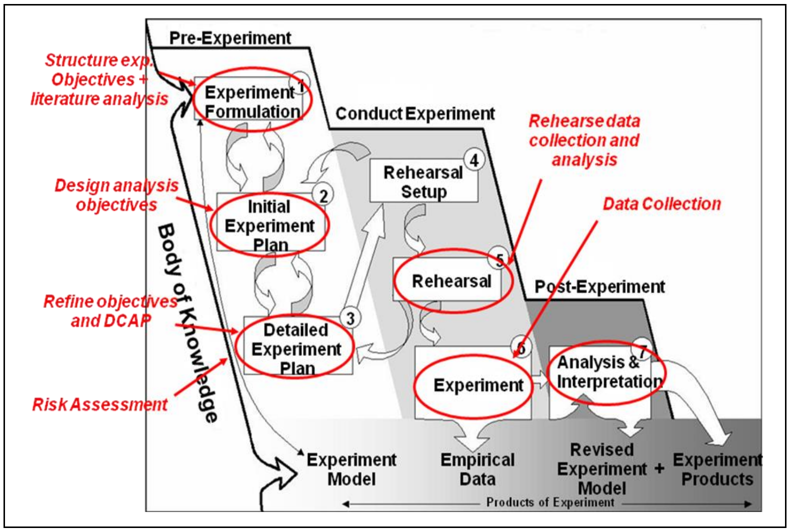

Figure 1 - Analysis in Experimentation

Figure 1 gives an overview of the steps involved in experimentation and highlights the areas in which analysis is actively involved. During the phase of experiment formulation, the analyst's task is similar to the task during the first phases of a CD&E project: structure the experiment objectives and conducting literature search in order to formulate the problem. For the experimenter the communication with the concept holder is of utmost importance to ensure the experiment support the concept's objectives. The same techniques and methods are used: brainstorming, SWOT, simple modelling etc. The analyst support the choice of the type of experiment depending on the stakeholders' expectations, the resource and time constraints and the assurance that the objectives can be addressed by the experiment type. Subsequently, in a team effort, the threats to validity and the risks to the experiments are assessed by estimating the probability of occurrence, the impact on the experiment conduct and ability to mitigate the risks through design changes, introduction of control groups, variation of methods and triangulation. The design must take into account the ability to obtain the measurements that are necessary to assess the concept.

From the experiment objectives, more specific analysis objectives are derived which are further decomposed in critical operational issues for which more detailed questions are formulated with associated metrics. Those form the basis of the data collection and analysis plan (DCAP). The DCAP is finalized before the conduct of the experiment to record the ability to address stakeholders' expectations, to ensure that data is and can be collected (requirements for Information Systems), and that all data collectors have a well-described task. The DCAP is part of the overall experiment design. Observation is the simplest form of data collection where the data collector simply observes without interference, but has the disadvantage of being subjective. Observation with interference is participation, which allows the analyst to experience and understand the issues, but which comes with the price of bias, subjectivity and a threat to validity. Interviews allow the analyst to go into more depth on key issues, but is time consuming. Surveys and questionnaires collect large amounts of data, are supposedly objective, but may not anticipate the relevancy of issues and the understanding of participants. Numerical data collection has the advantage of being objective, but is difficult to relate to cause and effect and lack context. The final report contains an analysis of the results of the experiment. Depending on the data collected and the hypotheses tested, the analysis can be descriptive or more numerical and statistical. In any case the analysis must validate or refute the hypothesis of the experiment.

4. CONCEPT MATURITY

The process of bringing a concept to closing is described in the CD Plan and executed through the CD&E project. The integrated campaign of analysis and experimentation ensures a spiral and iterative development of the initial idea to a final concept. Before a CD&E project can be closed, an assessment must be made whether the concept and its associated solutions, deliver against the expectations. The key questions to pose in the assessment of a concept are:

- Does the concept meet required capability needs across DOTMLPFI elements?
- Does the concept generate new requirements?
- Is the concept effective relative to current operating methods or competing concepts?
- What are the operational benefits and risks of implementing the Concept?
- Is it congruent with transformation or strategic vision?

The ultimate goal for the decision makers is to gain understanding of what the concept brings, and the task of the CD&E project is to provide advice on the utility and versatility of the concept and how to implement proposed solutions. The finalisation of the CD&E project is closely interwoven with the ability of NATO and the nations to implement the concept. However, it is often difficult to state whether the concept is in such a stage that it will lead to implementation, and sometimes the concept – with its attributed solutions – requires the development of supporting concepts, cannot be implemented without a simultaneous implementation of other measures, or cannot go forward without major commitments in the form of financial incentives, political will or military implications. Still, the closure of the CD&E project assumes that NATO and the nations have agreed with the outcomes of the project and can approve the concept document and acknowledge the proposed solutions. The question now becomes whether the approval of the nations – according to the CD&E Policy and Process, this approval is gained at the MC level – has consequences for the nations and NATO to implement the concept: approval for a number of concepts may be withheld when nations cannot oversee the affordability in terms of financial costs, political acceptability and military force structure implications. Naturally, concepts will not be approved if the ideas expressed in the concept are immature and not fully worked out, the solutions are not matching up with the ideas, or do not meet the stated expectations. When both the ideas and the matching solutions are sound, nations may stop further development when the concept is too revolutionary or radical resulting from out-of-the-box thinking, revolutionary technological solutions, or has far reaching (future) implementation consequences, particularly in the NATO environment where every decision is made with consensus, or when it is anticipated that consensus must be reached. It is a question how such impasses with respect to the further action that is needed for a concept to go further, a CD&E project can be finished and ultimate approval of the product can be reached?

4.1 Technology Readiness Levels

In the 1990 the R&T communities identified the need to define technology readiness levels to indicate how far an initial idea had progressed on the ladder of basic and applied research towards development and implementation with the ultimate goal to be ready for production. NASA introduced in 1995 the term Technology Readiness Level (TRL)[13] and these have been adopted in NATO by the Research and Technology Organization (RTO). The TRLs start out from principles, moves to the formulation of a technology concept and the subsequent proof-of-concept and validation in laboratory, followed by demonstration in an operational environment, towards 'mission qualified' and finally 'mission proven'. Basically, TRLs allow for the staggering of Basic Research, Applied Research, Technology Development (in short R&T), Research and Development (R&D), and Production. Within the project management world, a similar idea was developed, however, now the term maturity was introduced: the P3M3 (Portfolio, Programme & Project Management Maturity Model) model is a five-level maturity scale is used for processes that run initially ad hoc and chaotic, then are used repeatedly, becoming business standard, after which they are subject to management and finally are optimised[14]. In 2009 NASA introduced Concept Maturity Levels for the Space-Science Mission Concept[15], which is more applicable to the scientist (see Figure 2). These maturity levels may run parallel to the TRLs to some extent, but also introduce the management aspects that the P3M3 model demonstrates.

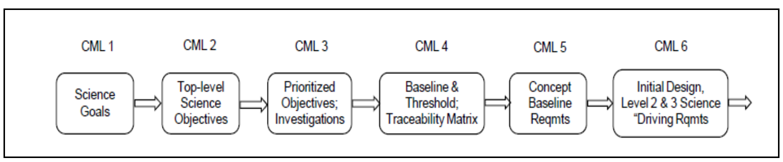

Figure 2 - NASA Space Science Concept Maturity Levels

Definition Of Technology Readiness Levels

TRL 1 Basic principles observed and reported: Transition from scientific research to applied research. Essential characteristics and behaviours of systems and architectures. Descriptive tools are mathematical formulations or algorithms.
TRL 2 Technology concept and/or application formulated: Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.
TRL 3 Analytical and experimental critical function and/or characteristic proof-of-concept: Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies. Demonstration of technical feasibility using breadboard or brassboard implementations that are exercised with representative data.
TRL 4 Component/subsystem validation in laboratory environment: Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.
TRL 5 System/subsystem/component validation in relevant environment: Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.
TRL 6 System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space): Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.
TRL 7 System prototyping demonstration in an operational environment (ground or space): System prototyping demonstration in operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.
TRL 8 Actual system completed and "mission qualified" through test and demonstration in an operational environment (ground or space): End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.
TRL 9 Actual system "mission proven" through successful mission operations (ground or space): Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place

4.2 Concept Maturity Levels

The introduction of a similar measure of maturity for concepts may assist the CD&E process to state whether the balance between ideas and solutions is reached, and whether the concept is in such a state to be handed over to ACO for full implementation. The latter is important, because fully matured concepts may then be furthered in the capability development process as Targets, either for nations or for NATO[16]. Any of the

13 John C. Mankins – Technology Readiness Levels, A White Paper, Office of Space Access and Technology, NASA, 6 April 1995

14 Portfolio, Programme, Project Management Maturity Model (P3M3) Public Consultation Draft V2.0 – Office of Government Commerce – Rod Sowden et.al, London, 2010

15 Concept Maturity Level – Establishing a Shared Language to Articulate Maturity of a Space-Science Mission Concept and Cost Uncertainty in the Early Formulation Phase – Gregg Vane, NASA Jet Propulsion Lab, 6 July 2009

16 NATO Defence Planning Process – Step 3 defines NATO and Nations' Targets as goals to be implemented

concepts that have a balance between ideas and solutions, but has not progressed to full maturity, is therefore in an intermediate stage. Figure 3 provides an attempt to define Concept Maturity in terms similar to the RTO's Technology Readiness levels. Care must be taken to not confuse the levels themselves to a higher level of maturity, as not all concepts are equal, nor do they have all have tangible results. The concepts that are overarching may not reach the higher levels of maturity, whereas operational concepts require the development of prototypes, testing and demonstration. Overarching concepts may reach a completion level where the ideas and solutions need to be saved but approval by the MC may not be attainable, because the nations cannot oversee the consequences of the concept. They may also need the development of supporting concepts to ensure that the ideas and solutions can be transferred to the NATO entities that can undertake implementation in due time. It may be so that approval for some concepts need to be sought at a lower level, e.g. at SACT, or Bi-SC level, before further evidence can be presented to the MC, that the concept is fully matured. Some concepts may be too radical in their thinking or costly in their solutions that they cannot be accepted by all nations, and therefore have to linger in the 'purgatory' before being approved. That should not preclude nations from adopting these concepts on their own, or within a coalition-of-the-willing (within NATO). That step has the added benefit that nations can demonstrate in their national implementation of the concepts' ideas and solutions that the concept is sound or may need modification. Also it may convince other nations to adopt the concept, after which MC approval can still be attained. To ensure that a CD&E project can close and that the resulting products can be approved – at which ever level – the only need for the project is to ensure that a certain maturity level is reached. The project can even declare beforehand which level they are targeting for.

1.	Initiation: Principle idea is formulated
2.	Operational Validity: Customer expresses the need and states requirements for development of the principle idea
3.	Applicability: Positive identification of a concept void and research on the applicability of the concept within operational environment
4.	Identification: Component conceptual solutions likely to fulfill stated requirements
5.	Feasibility: Analytical proof that conceptual solutions acting as required in a simulated environment
6.	Prototyping: Proof-of-Principle building of integrated concept solutions
7.	Prototype Validation: Solutions are operable in laboratory environments
8.	Solution Validation: Solutions are operable in operational environment and validated through a military assessment
9.	Solution Integration: Developed block-solutions integrated into full solution fulfilling requirements over the DOTMLPFI spectrum
10.	Demonstration: Full implementation in all DOTMLPFI areas

Figure 3 - Concept Maturity Levels

The need to address Concept Maturity in a paper that highlights Operational Analysis support to CD&E is made to provide additional structure to the process of Concept Development. As we are confronted with more complex or wicked problems, criteria for when to stop and to know when to stop are becoming a necessity. The author understands that the proposal above must be vetted and scrutinized, but adoption of Concept Maturity Levels may support also the closer integration of Concept Developers and Experimenters, who have a tendency to operate separately. It is remarkable that the GUIDEx discusses concepts always in the context of Defence Experimentation, while the NATO CD&E policy has a tendency to let the experimentation be a conduit by which the concept is validated, putting the concept in a central role. In either case, a role for operational analysis has been recognized as a way to provide quality control for the concept itself, the CD plan and the experimentation efforts.

5 CONCLUSIONS

In the early stages of concept development, analysis can determine stakeholders' interests and expectations, the operational value and feasibility of a concept through a number of brainstorming sessions, and determine possible venues for development by addressing operational validity and effectiveness through gaming, modelling and simulation. As the problem has been identified and structured, analysis itself provides the rational-deductive method to determine what the solutions to the problem could be through analytical studies, requirements analysis, modelling and simulation or operations research, while at the same time war-games, human-in-the-loop simulations and live experiments can be conducted providing the empirical-deductive way to prove which solutions are solving the problem. This is substantiated in an integral campaign of analysis and experimentation, which supports a spiral and iterative development of concepts to maturity. In the experimentation efforts, the analysis activities look to accumulate evidence to determine and demonstrate the validity and increased effectiveness of the proposed solutions. From analytic games to live experimentation, care must be taken for a robust and rigorous experiment design which takes into account the four basic principles of experiment validity and a risk mitigation process. In summary analysis provides a 3-tier enabling function to CD&E:

1. Initial Concept Analysis: identify the problem, structure it, state stakeholders' interests and determine operational value and feasibility;
2. Analytical Studies: derive from assumptions and characteristics of the operational environment, the solution through rational deductive reasoning involving scientific methods of study;
3. Analysis of Experiments: conduct an analysis of an experiment by comparing expectations and results to prove whether the experiment aims have been met.

As the CD&E methodology is scientifically supported, the rigour with which this support is applied determines greatly the quality of the concept, its validity, feasibility and applicability. During the initial conceptual phases of the CD&E project, the application of sound scientific and analytical methods will guarantee that further development rests on a solid foundation. Critical views embedded within accepted scientific culture and practice will provide the project with a thorough understanding why the project is undertaken, for whom and what the content is. In an analytical study, the methods of deriving results must be build upon a proper representation of the reality in calculations, models and simulations, and adhere to a strong scientific discipline. During experimentation the scientific methods applied will allow for the proper establishment of acceptance or rejection of hypotheses, valid and useful discovery and well founded validation and test plans.

Within NATO, CD&E is well founded with the establishment of a CD&E Policy and Process. The need for definition of concept maturity is expressed. Cooperation between the Concept Developer, the Experimenter and the Analyst will provide a good breeding ground for defence studies, experimentation and solution finding in NATO.